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Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE ALFALFA WEEVIL AND METHODS OF CONTROLLING IT.[1]

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INTRODUCTION.

The alfalfa weevil destroys a great deal of alfalfa in northern Utah and southern Idaho. It also inhabits southwestern Wyoming and is spreading slowly to new territory in all directions. It may in time infest most of the United States. The adult (fig. 1), a small brown snout-beetle, and the larva (fig. 2), a green, worm-like creature, usually escape notice during the first two or three years that they are present in a locality, but as soon as they become numerous enough to do harm they are readily found, and their effect upon the appearance of the fields is conspicuous. Vigorous treatment is then necessary to prevent partial or total destruction of the first and second crops. The purpose of this bulletin is to show how serious the attack is to the farmer, how much territory it embraces and how it spreads, and to describe the insect, its work, and the methods which are effective in dealing with it.

FIG. 1.—The alfalfa weevil: Adult. Enlarged. (Original.)

[1] *Phytonomus posticus* Gyll.; order Coleoptera, family Curculionidae.

NOTE.—This bulletin describes the work and spread of the most dreaded pest of alfalfa in the United States. It is of interest in the region west of the Mississippi River, particularly Utah and the adjacent States.

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IMPORTANCE OF THE ALFALFA WEEVIL AS A PEST.

This insect attacks Utah's most important crop. Alfalfa furnishes 80 per cent of the value of the hay and forage of the State, which in turn is 40 per cent of the value of all crops. The 1909 crop was worth nearly $6,000,000.[1]

About one-half of the annual yield is harvested in the first cutting and about one-third in the second. The damage to the first cutting ranges from slight depreciation of the quality of the hay to almost total loss, varying according to the rate of growth and the time of harvest; it may be estimated at 50 per cent. The damage to the second cutting, if no effort is made to prevent it, amounts to total loss. The menace to this State, therefore, involves one-half the yield, worth $3,000,000.

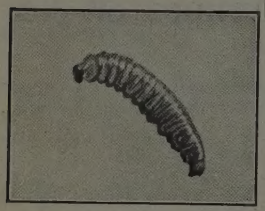

FIG. 2.—The alfalfa weevil (*Phytonomus posticus*): Larva. Much enlarged. (Original.)

Besides the loss represented by these figures, there is a less tangible but equally serious effect due to the peculiar relation of alfalfa to western agriculture. Because of its ability to revive after prolonged drought, to produce abundant crops for many years without reseeding, and to furnish a nearly complete ration for live stock, it has a very great value for a region where the water supply is scanty, reseeding expensive and difficult, and live stock an important and increasing source of wealth.

THE INFESTED DISTRICT.

The infested district (fig. 3) reaches north from Salt Lake City to Rosette, Utah; Strevell, Malad City, and St. Charles, Idaho; and Cokeville and Granger, Wyo. It extends south to Moroni and Oasis, Utah. These points lie near the rim of a circle about 100 miles from Salt Lake City. Eastward the weevil has gone only about 50 miles to the Uinta Mountains and westward an equal distance to the Salt Lake Desert.

SPREAD OF THE WEEVIL.

Both the outline of the infested district and the history of the spread show an average seasonal advance of about 10 miles per year since 1904 or 1905, when the insect was discovered by farmers at Salt Lake City. There are no isolated colonies distant from the main body, and there have been no long jumps in the movement. If wagons and railroad trains have carried weevils it has evidently been only for short distances. As has been predicted,[2] their spread has been largely by crawling and flight. The greatest progress has been along

[1] Thirteenth United States Census.

[2] Utah Agricultural College Extension Department Bulletin No. 1, 1909.

certain wagon roads, rather than in the direction of prevailing winds, railroads, or streams. This point is well illustrated by the road to St. Charles, Idaho. Here the insect has gone 100 miles along a main road, across mountain ranges, regardless of prevailing winds, and far from railroads.

That no one knows exactly how the weevils spread, may be inferred from the conflicting quarantine regulations designed by uninfested

FIG. 3.—Map of portions of Utah, Wyoming, and Idaho, showing the district infested by the alfalfa weevil. The circles are 50 and 100 miles from Salt Lake City. (Original.)

States to exclude them. Thus, Arizona forbids the importation of nursery stock; California requires its fumigation at origin and delivery and forbids packing with hay, straw, or rushes; Idaho differs from California in permitting the use of rushes; Montana requires official fumigation at the point of origin; Oregon forbids the use of rushes and forage plants as packing; Arizona prohibits the importation of fruits; Montana, the importation of both fruits and vegetables from April 1 to October 31, except such as are inspected at designated points by the State of Utah from August 1 to October 31. Arizona and Oregon

prohibit the entrance of alfalfa seed; California and Idaho require it to be fumigated by an official after arrival; and Montana requires it to be so fumigated before shipment. Hay and straw of all kinds are barred by all five States. Bees in hives are refused admittance by California and Idaho; and Oregon requires that they shall not be packed in rushes, weeds, or forage. Household goods must be inspected before shipment into Arizona. Live stock can be shipped into Arizona only with the consent of the State entomologist and must be transferred to clean cars before crossing the line. California and Idaho prescribe that hay and straw must not be used in cattle cars, and Oregon forbids also grass and forage crops. Grain is barred from Arizona. Colorado, Wyoming, New Mexico, and Nevada have no restrictions on account of the alfalfa weevil.

In spite of the contradictory popular ideas of the means by which the alfalfa weevil travels, many facts which bear upon the question are definitely known. Live weevils do not occur in alfalfa seed, either before or after it is recleaned. They are seldom found in nursery packing of any kind, fruits and vegetables, or hay and straw used for packing, bedding, or feed, except under the following conditions: They are often found in green alfalfa fresh from the fields and in second-crop hay and potatoes which have been handled in contact with it; and they are found also in cured alfalfa hay, especially hay of the second cutting, in the stack, where some of them remain alive until the end of the following winter. They are found for several hours afterward in clothing which has been worn through infested fields in summer time, and sometimes remain even after the clothing has been packed in a trunk and shipped as baggage.

The occurrence of weevils in green alfalfa hay and new hay of the second crop is particularly important, because potatoes which are to be shipped are often hauled to the car upon a bedding of it to prevent bruising and are sometimes covered with it to protect them from the sun. This hay usually contains weevils, which crawl from the alfalfa to the sacks and are loaded into the tight refrigerator car, in which they often remain until it reaches its destination. Although no colonies have yet been started by this means, there is constant danger of it, which can be minimized by simply keeping the hay away from the potatoes.

Another important consideration as to the occurrence of weevils in new hay is that many people driving through the country in summer carry it for short distances as feed for their horses. The weevils may leave the hay as a result of the jar of travel, according to their habit; and that they do so is the more probable because no colonies have been found at any distance from the main territory, as would have happened if they were carried long distances by wagon. There is, however, a constant stream of traffic over certain main roads, composed of sheepmen, peddlers, and others bent on

business or social visits to other localities, near or remote. The carrying of weevils by these people, even if it be but for a mile or two, amounts in the aggregate to a systematic relaying of the species over through routes. There seems, in fact, to be a relation between the localities where alfalfa from infested fields is carried in this way and the country over which the weevils have spread most rapidly.

No connection can be traced between the railroads and the actual spread of the alfalfa weevil; in fact, the advance of the weevils has been rather less rapid along some railroads than in certain regions remote from them. The weevils occur rarely in baggage, express, and freight cars, and somewhat more often in passenger cars and refrigerator cars containing potatoes which have been handled with fresh second-crop alfalfa hay. Although there has been a large volume of unrestricted passenger traffic from the infested region during the past 12 years, no colonization of weevils has resulted; and although weevils have traveled in potato cars as far as Denver, Colo., Rock Springs, Wyo., and Butte, Mont., and many cars of potatoes which doubtless carried weevils were shipped throughout the Western States, no colonies have been started by this means.

The transportation of weevils on railroad trains and wagons is little affected by the flying of the species. It seemed reasonable at an early period of the investigation to believe that a beetle which flies abroad in the summer would alight upon various commodities and vehicles and be carried for great distances, but such is not the fact. Weevils are rarely found on trains or wagons except in cases where new hay is involved. The flight of the weevil not only plays a small part in its distribution by wagons and trains, but it is less general and extensive than it was once supposed to be. All records which are definite and authentic show only small numbers of the weevils in flight at any time. Reports dealing with immense numbers swarming in the air usually mention no specimens at all as actually caught, identified, and counted. They do not agree with the observations of this bureau, and many of them are probably based, by mistake, upon some other insect, such as the dung-beetle, Aphodius, which resembles the weevil in appearance and is always present in the air in larger numbers than the latter.

There is no evidence that the weevils ever fly for the purpose of seeking fields of alfalfa, either new or previously infested, or to find hibernation quarters. The most plausible theory is that their flight is caused by a rise in temperature, as are many activities of the lower animals. So far as can be learned, this flight is at random. It takes some of the weevils into new fields.

The crawling of the larvæ is unimportant as a method of spread, being limited to a journey of a few feet from one field to another, but the crawling of the adults is an important matter. During the cold weather of spring and fall a day's journey of an adult weevil is

only a few inches, but during the warm months the adults crawl during the greater part of the day or, in July and August, of the night. Although they use up much of their energy in climbing up and down plants, and into and out of crevices in the ground, so that it is largely wasted so far as progress is concerned, a little of it happens to lead to new fields. There is no general movement by crawling, any more than by flight, from the fields to the ditch banks, fence rows, and similar places, or from such places to the fields, at any time. The crawling is most important, as has been shown, in bringing weevils into hay and so into traffic, which probably takes them somewhat farther than they could go without help.

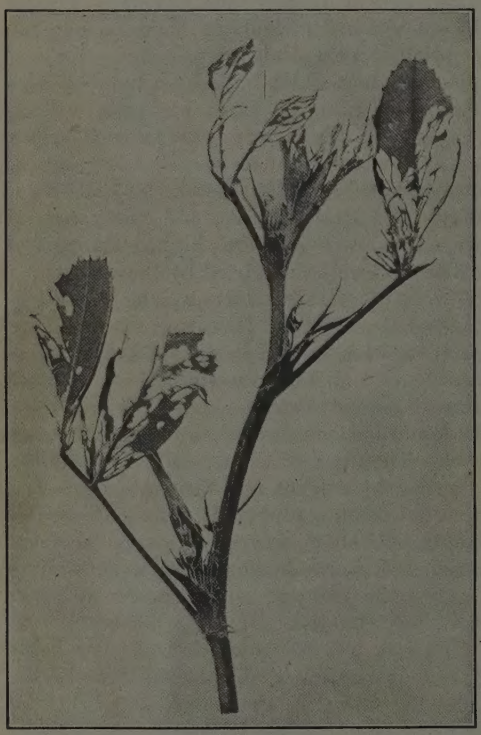

FIG. 4.—The alfalfa weevil: Work of the larvæ. (Original.)

During the 12 years that the alfalfa weevil has been in America it has spread into new territory very slowly and has agreeably disappointed those who feared that it would extend rapidly over all the alfalfa-producing regions of the continent. Its progress is so slow that there is hope of providing control methods for new climates and conditions as fast as these are encountered. There is hope also that the pest will not prove equally injurious under all circumstances. It is much less harmful in Europe than in America, owing apparently to climatic and industrial conditions, and it multiplies more slowly and does less damage in the higher altitudes in Utah and Wyoming than in the lower valleys. Nevertheless, it is possible that eventually every section of the country will have to consider, first, the problem of keeping the insect out of its boundaries, and later, the problem of growing alfalfa in spite of the weevil, or finding

a substitute for that valuable crop. It is therefore particularly desirable that farmers in the western mountains and plains should learn the appearance of the different stages of the weevil and be prepared to protect their crops.

DESCRIPTION OF THE WEEVIL IN ITS DIFFERENT STAGES.

THE FULL-GROWN LARVÆ.

The insect is most easily discovered, during the early years of its presence in new fields, in the form of the full-grown larva (fig. 2). It is then a green wormlike creature one-fourth of an inch long, with a black head and a faint white stripe down the middle of the back, and it feeds upon the leaves of the alfalfa mainly during late May, June, and early July. It can be found by sweeping the tops of the plants with an insect net, or by looking for the notches in the leaves where it has fed. When the larvæ are numerous they destroy most of the tender growth (fig. 4), causing the tops to appear white and making the field look at a distance as if frostbitten.

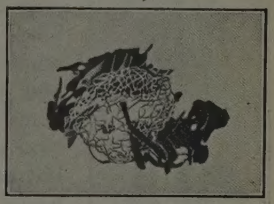

FIG. 5.—The alfalfa weevil: Cocoon attached to dead leaves. Much enlarged. (Original.)

THE NEWLY HATCHED LARVÆ.

The newly hatched larvæ are harder to find. They are only about one thirty-second of an inch long and remain hidden in the partly unfolded tips of the plants, where they are not easily seen or caught by the net. Their color is yellowish green, excepting the head, which is black. The color changes to green at the first molt, or shedding of the skin, and there is little change except in size during the two or three molts which follow, varying in number with the season of the year in which the larval life is spent.

THE PUPÆ AND COCOONS.

The pupal form is the one in which the change from the larva to the adult takes place. The pupa is contained within a delicate, oval, netlike cocoon (fig. 5), woven of a few white threads and attached, sometimes to the lower part of a green stem, sometimes to rubbish on the ground, and often to the inner side of a curled dead leaf. The pupa within this cocoon is somewhat like the larva in color, but more like the adult beetle in form, becoming still more like it in both respects as it approaches maturity.

THE ADULTS.

The adult is harder to find than the larva, but is present in the field throughout the whole year instead of the summer only. It is an oval brown beetle, three-sixteenths of an inch long, with a prominent snout projecting downward from the front of the head. The

color of old, weathered specimens is nearly black, owing to the dark ground color revealed by the shedding of the brown and yellow scales which at first clothe its upper surface. The adult stays close to the ground during early spring and late fall, but climbs about in the tops of the plants during the warm season. It is not readily seen by one walking through the fields, because it habitually drops to the ground when disturbed, and its color helps to make it invisible. It can be captured during the warm weather by sweeping the plants with a net and during the cooler spring and fall weather by sitting quietly in the field and catching it when it moves on the ground. In the winter it can be found by digging about the crowns and roots of alfalfa plants.

FIG. 6.—The alfalfa weevil: Eggs in split green stem. Enlarged. (Original.)

THE EGGS.

The eggs (fig. 6) are less conspicuous than the larvæ and adults, because they are usually concealed within the stems of the plants; but the holes in which they are placed are found in large numbers by examining the green stems during May and June, and in smaller numbers as early as March and as late as December. The eggs are small, oval, shiny globules, bright yellow when first laid, but dingy after a few days when incubation has begun, and adorned during the latter part of the incubation period with a black spot where the head of the little larva shows through the transparent shell. A few eggs, some of them infertile, are laid on the outside of the plants, and more in the weeds and grasses which grow in the field. Late in the fall and early in the spring there are many in the dead stems on the ground.

When an alfalfa grower outside the territory known to be infested finds in his field any insect which he suspects to be a form of the alfalfa weevil, he should send it to the Bureau of Entomology field station at Salt Lake City, Utah, to be identified. If it proves to be the alfalfa weevil, it is important that work should begin without delay, so that the measures that will be effective in controlling the pest under the new conditions may be learned. This work requires study of the traveling, feeding, mating, and egg-laying habits of the insect; of the effect upon it of climate, crop conditions, and farm operations; and of the agricultural conditions of the region, in order that the conditions favoring the growth, increase, and work of the weevil and the conditions necessary to destroy it or hinder its work may be ascertained. So far as these things are already known in regard to the country now occupied by the weevil they are here set forth.

HABITS OF THE WEEVIL.

WHERE AND HOW THE WEEVILS PASS THE WINTER.

When cold weather comes on the adult weevils creep down close to the ground and into crevices and spend the winter there. Some ditch banks and other uncultivated places which are strewn with the litter of dead vegetation harbor many of them, but these numbers are an insignificant part of those which remain in the fields and deposit eggs the following spring. Burning the grass and weeds in such places, therefore, while desirable in itself, gives practically no protection to the crop in neighboring fields.

Many weevils die in the fields during zero weather, but milder winter temperatures seem to have little effect upon them. Since bare ground freezes more than that which is covered by snow, it is sometimes advisable to cultivate the field in the fall, so that the snow which falls upon it may melt and expose the weevils as much as possible to the cold.

Owing to the fact that most of the weevils spend the winter on the ground in the fields, it is possible to kill them by flooding the field with muddy water and thus covering it with sediment.

There is no definite hibernation in this species. The adults are quiet when it is cold and active when it is warm. A female taken from the frozen fields will feed immediately and oviposit in a few hours after being brought into a warm room.

EARLY SPRING ACTIVITY OF THE WEEVILS.

The readiness with which the weevils resume their activities when subjected to warmth has an important bearing upon control measures. The weevils lay scattered eggs in early spring, many weeks before the regular laying season, and deposit numbers of eggs in the dry stems on the ground even before they begin climbing up the green plants and feeding upon them. Larvæ hatching from these eggs, with those from eggs laid under similar circumstances the previous fall, sometimes attack the plants in numbers large enough to cause serious injury to the crop before the majority of the eggs have been laid, particularly in years when there is an early spring. This early activity must be taken into account in any attempt to protect the first crop.

The fact that the adults feed rather freely for several weeks in early spring while the plants are small is the basis for attempts to destroy them by spraying with arsenical poisons. There is no danger of poisoning the live stock which may eat the hay, because the plants are too small at the time of spraying to hold much poison, and this early growth forms but a small portion of the hay crop. The amount of poison contained in hay from fields which have been sprayed only three weeks before cutting is too small to have any effect upon the most sensitive animals. The feeding of the adults is done chiefly after the usual time for the dormant spraying of orchards and before the early codling-moth spraying, and therefore

the work on the alfalfa fields need not conflict with either of those operations. Aside from its relation to spring spraying, this early feeding of the adults is chiefly important in that it gives the spores of Sackett's disease a chance to lodge within the tissues of the plant.[1] The damage caused by this blight is sometimes as serious as that done by the weevil larvæ themselves and is generally confused with it.

EGG LAYING OF THE WEEVILS IN LATER SPRING.

After feeding for several weeks, running about over the ground, depositing eggs in dry stems, and flying a little, the adults deposit large numbers of eggs in living stems. When the spring opens early they begin egg laying gradually, and the earliest eggs may hatch before the majority are laid. After a late spring the egg laying begins abruptly. In either case it is usually ended before June 10, and if the eggs can be destroyed up to that date, the attack of the larvæ will be prevented for the year. This can be done by pasturing the first crop so as to destroy the eggs after they are laid and before they hatch, or, at latest, while the larvæ are still small enough to cling to the leaves and be swallowed. This is the basis of the pasturing method and of a similar method of destroying the eggs and at the same time utilizing the first crop by cutting the alfalfa green and feeding it as a soiling crop.

WORK OF THE LARVÆ IN THE FIRST CROP OF ALFALFA.

If none of the treatments mentioned has been used, the larvæ appear in large numbers about the last week of May, or earlier if the spring has been favorable, and eat the leaves, especially on the young shoots, so rapidly that the plant is unable to outgrow the injury. At this stage, or a little earlier, it is necessary to cut the crop regardless of its condition, in order to prevent severe and perhaps total loss. The results of spring cultivation show at this time. The fields which have been cultivated grow earlier and produce a larger yield before cutting becomes necessary than do those which have been neglected. A few of the larvæ have finished feeding and spun their cocoons before even an early cutting. Most of the others spin during the month of June, though a few late larvæ are abroad in the field until winter.

When the first crop is removed, if the ground is dry and the weather clear and warm, many larvæ, pupæ, and adults die as a result of exposure to the heat of the ground. This mortality is increased if the ground is cultivated in such a way as to fill the cracks, crush the clods, and scrape off all remaining vegetation. This, in turn, is more easily accomplished if the soil has been kept in good condition by manuring and cultivation. The killing of the insects by heat is the foundation of the "brush-drag" treatment.

[1] O'Gara, P. J. Bacterial blight of alfalfa in Salt Lake Valley. *In* Science, n. s., v. 39, no. 1016, pp. 905, 906. 1914.

SUMMER FLIGHT OF THE ADULTS.

The heat of the soil is also probably an important cause of that increase in the activity of the adults called the summer flight, which is greatest during the dry, hot weather beginning in June and ending in August. This flight accounts for the presence of many adults in grassy places and orchards, where they alight and find protection from the heat. It helps to restock fields in which the weevils have been killed and makes it necessary to repeat the treatment year after year, and on the borders of the infested district it contributes to the spread of the pest. The summer flight is not a general movement of the weevils from the fields to seek more suitable hibernation places elsewhere. There is no such movement, and virtually all of the weevils spend the winter in the fields.

WORK OF THE LARVÆ IN THE SECOND CROP.

If no treatment is given the infested field after haying, the larvæ which have been feeding upon the first crop gather upon the buds of the stubble, and although many have been killed by the heat of the earth after the cutting, there are still enough to prevent the sprouting of the second crop for a time nearly equal to its usual period of growth. By that time most of them have finished their feeding and growth and have gone into the pupal stage, and there is consequently no attack upon the later growth.

ACTIVITIES OF THE NEW GENERATION OF WEEVILS IN SUMMER AND FALL.

At the time of cutting the second crop the fields are full of weevils of the new generation, and there are usually many more weevils in the second-crop hay, which is cut at this time, than in that of the first and third crops. Their activity is greater at night than by day, and this condition continues until the cool nights of September begin. As autumn progresses, they haunt the plants less and less and fortunately are nearly all on the ground before the thrashing of the seed begins. No live weevils have ever been found in alfalfa seed.

About one-half of the females of the new generation of beetles are ready to deposit eggs by the middle of October, and egg laying, chiefly in dry stems, goes on for about a month after that time. Few of these eggs hatch before winter, and some of them hatch the following spring and probably take part in the early attack upon the first crop.

These habits of the weevil and the relations between it and the crop, the climate, and the country, comprise most of the facts for which a practical use has been found. Upon them are based all effective plans for preventing its ravages and retarding its spread.

RECOMMENDATIONS FOR THE CONTROL OF THE WEEVIL.[1]

SILTING.

Weevils can be killed in late winter or early spring by irrigating the fields with very muddy flood water and so burying them under

[1] In the field tests of spring and fall cultivation and the dust-mulch treatment the Bureau of Entomology has had the cooperation of the entomological department of the Utah experiment station.

a deposit of fine mud. This is practicable only where the irrigation system is without a settling reservoir, which is in itself an undesirable condition, but in the few cases where it can be applied the process is simple and inexpensive and the results good.

SPRING CULTIVATION.

Alfalfa fields in a weevil-infested region should be cultivated thoroughly in the spring with the spring-tooth harrow, disk harrow, or a similar tool, provided the crop is valuable enough to warrant the expense of the operation. Under conditions where cultivation is especially desirable, as where water is scarce or the soil does not naturally retain moisture well, this may increase the amount of the first crop as much as 50 per cent. It will cost from 60 cents to $1.25 per acre. In nearly every case it will be necessary to go over the field at least twice; and if the soil is in such condition that a double harrowing does not pulverize the soil and kill the weeds and grass, systematic manuring, cropping, and cultivation to improve the soil are desirable. Spring cultivation has no appreciable effect on the weevils, but merely hastens the growth of the alfalfa so as to give a larger yield when the attack of the larvæ in May or June makes early cutting necessary.

SPRING SPRAYING.

As soon as the weevils begin feeding upon the leaves of the plants, which usually happens early in April, the field may be sprayed with from 50 to 100 gallons per acre of a mixture of arsenite of zinc and water, in the proportion of 4 pounds of powder in 100 gallons. Owing to war conditions it may be impossible to obtain this poison at the present time. Arsenate of lead has not so far proved successful as an early spring spray.

On several occasions when it was intended to spray fields in early spring, circumstances prevented it, and the spray was applied about May 1, after many larvæ had hatched from the eggs and attacked the crop. In several of these cases the results were good, although the amount of foliage which must be covered is larger at this time than in early spring. Arsenate of lead, in the usual orchard strength of 4 pounds to 100 gallons of water, was as effective at this time as arsenite of zinc.

The attachment which is recommended for use with the hand-pump or gasoline-engine outfit for spraying alfalfa fields resembles the potato or beet sprayer. It is a horizontal pipe, 3 feet above the ground, fastened across the back of the truck of the power sprayer (fig. 7) or the wagon in which the hand pump is carried, and stiffened by lashing to a 2 by 4 scantling as long as the pipe itself. To provide for the attachment of the supply hose from the pump and the nozzles which distribute the liquid, the pipe is built up of 30-inch pieces of one-half inch galvanized iron pipe, coupled by T's, except

at the middle, where a cross is used, and the ends are fitted with L's. Unless reducing T's, L's, and cross can be obtained, a $\frac{1}{2}$ inch by $\frac{1}{4}$ inch bushing must be used for each nozzle, and in either case the attachment is made by means of a short one-fourth inch nipple. The hose lead from the pump is attached by means of a hose coupling. There should be a stopcock between the hose coupler and the main pipe to cut off the flow and maintain pressure whenever it is necessary to stop spraying in order to clean or repair nozzles.

The number of joints of pipe and nozzles to be used depends upon the capacity of the pump. A $2\frac{1}{2}$ horsepower engine and a good pump will supply seven nozzles of the eddy-chamber type, with $\frac{3}{64}$ inch holes in the disks, and maintain a pressure of 150 to 200

FIG. 7.—Alfalfa sprayer with power pump, in use against the alfalfa weevil. (Original.)

pounds. Some hand pumps will hardly supply three nozzles The nozzles are likely to become clogged, no matter how much care is taken to have the solution and the apparatus free from foreign particles. In addition to such precautions, therefore, it is wise to use nozzles provided with direct cleanouts at a slightly higher cost, as the time saved in operation makes up for the extra cost. Before work is begun, the tank, pump, hose, iron pipe, and nozzles should be thoroughly cleaned to remove particles of rust, sediment, and other foreign matter. The water and poison should be screened through fine brass strainer cloth. Attention to these details makes the difference between economical and expensive spraying, as clogging of the nozzles means costly delay for the entire outfit.

The cost of spraying with a power sprayer will depend largely upon the distance water must be hauled. It should range from 70

cents to $1.05 per acre when the usual price is paid for poison, the use of machine, the services of the operator, and the labor of the team and driver. Spraying does not take the place of spring cultivation in improving the condition of the soil and hastening the growth of the crop, nor does cultvation take the place of spraying in preventing the work of the weevils. The two operations are independent of each other, and in many cases both are desirable.

PASTURING.

If spraying is out of the question, the first and second crops may be protected by destroying the eggs after they have been laid in green stems, or the small larvæ after they have hatched and begun feeding in the tips, by pasturing the field. The success of this as a method of killing the insects depends upon managing the grazing in the right way and continuing it until most of the eggs have been laid; that is, until after the usual cutting time of the first crop. Instead of being pastured over the entire area at once, the field should be divided into two or three lots, with fencing suitable for the kind of live stock that is to be used, and the lots should be pastured alternately, so that each, after being eaten down close to the ground, will have a chance to grow up before the animals are turned in again. The number and size of the lots should be proportioned to the producing power of the field and the number of animals to be pastured, so that each lot may be grazed close to the ground about once in two weeks.

The pasturing may begin as early as the growth of the alfalfa will permit, and the change from each lot to the next should be made as soon as the larvæ which have developed in the next lot begin to feed upon the plants. On the other hand, the change should not be made until the lot which is being pastured has been grazed close. The number of animals which are necessary is regulated by these requirements, varying at different times with the rate of growth of the alfalfa. It may sometimes be advisable, when the stock has eaten most of the lot clean but allowed the plants to grow tall in certain spots, to mow these spots rather than to compel the animals to graze them.

The work may be considered finished as soon as most of the weevil eggs have been laid, which means a little later than the usual cutting time of the first crop. A good, practical method of deciding this question is to continue the pasturing until the lot containing the oldest growth continues free from signs of larval feeding past the time when the appearance of larvæ is to be expected, according to the experience of the season.

The area which can be protected from the weevils in this way is limited by the amount of live stock available. Three and one-half

acres of rather poor alfalfa handled in this way will support from forty to fifty 60-pound hogs, or a corresponding number of other animals.

According to the statements of agricultural experts, this way of preventing weevil injury deserves more notice than its usefulness for that purpose alone warrants, owing to the fact that, when combined with the proper feed of grain, alfalfa pasture furnishes an economical method of fattening live stock. Many farms would probably be more profitable if their management centered about the pasturing of stock on alfalfa, with the growing of enough other crops to provide grain and forage throughout the year. This is a matter that each must work out for himself to suit local conditions. Wherever the pasturing method is practicable it will solve the alfalfa-weevil problem.

SOILING.

Cutting the alfalfa green two or three times during the season and feeding it gives results similar to those of pasturing. It is especially suitable for dairy farms.

THE DUST MULCH.

If the weevils have not been killed earlier, they may be destroyed after removing the first crop by removing nearly all the vegetation, crushing the clods, and filling the cracks so as to expose the entire surface of the field to the sun. This is best done by such cultivation as will cover the field with a dust mulch, the dust being an additional means of killing the weevils which escape the heat of the ground. Success depends largely upon doing the work when the ground is dry and the weather warm and bright. It should not be attempted in cold, cloudy, or wet weather, nor soon after irrigation.

Dragging the field twice with a brush drag is sufficient if the soil is already mellow, but most fields need one or two cultivations with the disk or the spring-tooth harrow, and some grassy fields with heavy soil can not be put into the best condition to kill weevils until after they have been systematically improved for several years. A tool which is used instead of the brush drag in Salt Lake Valley is built by stretching several layers of heavy woven-wire fencing under an ordinary spike-tooth harrow with the teeth laid flat, and adding enough weight to pulverize the soil.

The dust-mulch method has practically no value as cultivation, since it must be followed by irrigation, which packs the surface dirt and restores it to the condition which obtained before cultivation. Its value depends entirely upon the fact that it kills the insects and so permits the second crop to grow. It is open to the objections that it requires time and the labor of men and horses during the busiest season of the year and that it stirs up the stones on rocky fields.

SUMMER SPRAYING.

Many farmers have sprayed the stubble after removing the first crop, with results about equal to those of the brush-drag treatment. The same apparatus can be used as for the spring spraying, but the usual method has been to distribute the spray through two leads of hose and two Bordeaux nozzles, each handled by a man who walks behind the outfit or rides upon it and covers the ground as evenly as possible and as far as he can reach with the spray rod. Both Paris green and arsenate of lead, in the usual orchard strengths of 1 pound and 6 pounds, respectively, per 100 gallons of water, have been successful.

This treatment is more rapid than the brush-drag method, but it requires special machinery. For orchard districts it is very promising.

PUDDLING.

Several farmers have protected the second crop by dragging the stubble, while it is still wet from irrigation, with the land leveler or the clod breaker. This process embeds the insects in mud, in which they perish, and effectually prevents them from attacking the sprouts. It is easier than the dust-mulch method, but it is harmful to the soil and is not recommended.

PREVENTION OF SPREAD.

Equally important with the problem of coping with the weevil in the fields is that of preventing its spread into new territory or, at least, since that may be impossible, of giving it as little help as possible. Aside from the consideration that the prosperity of each section depends largely upon that of other sections, the spread of the weevil from one district to others is a distinct detriment to the former as well as to the latter in that it increases the distance from which hay for feeding purposes must be shipped and consequently increases its cost.

All commodities which are to be shipped or hauled out of infested territory should be kept from contact with growing alfalfa, and they should at all times be kept away from new alfalfa hay, particularly that which has been cut during July and August.

SUMMARY OF RECOMMENDATIONS.

The first and second crops of alfalfa can be protected from the alfalfa weevil by spraying the young growth in early spring, by proper pasturing, or by cutting and feeding the crop before the eggs in it have hatched, and in a few cases by covering the field with silt in early spring. The growth of the alfalfa can be stimulated and a larger yield obtained by cultivating the field in the spring. The second crop can be protected by spraying the stubble or by the dust-mulch treatment.

Care should be taken to avoid spreading the weevil by shipping out of the infested district either new alfalfa hay or articles which have been in contact with it or with growing alfalfa.

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